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TRANSVERSE SHEAR STRESS DISTRIBUTION
IN CIRCULAR METALITE PLATES

A Thesis
Submitted to the Graduate Faculty
of the
University of Minnesota

by
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for the
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PREFACE

Sandwich type materials, being used as structural members in aircraft, present certain problems of analysis due to their non-homogeneity. Sandwich materials consist of a relatively thick, low density core to which are bonded two thin, high density face plates. When a load is applied to such a material shear stresses are set up in the core. As far as is known, no attempt to analyze these shear stresses has been made.

The writer, using a method suggested by Prof. J. A. Wise, University of Minnesota, has attempted to measure the shear strains occuring within the balsa wood core of a circular panel of Metalite. These strains were then converted to equivalent stresses. The metalite panel was furnished by Chance Vought Aircraft, Dallas, Texas. Some of the test equipment was made by Mr. C. H. Gates, who has done some valuable preliminary work on this problem.

An analytical approach to the stress distribution has also been derived in this paper and an attempt to correlate the analytical and experimental results has been made.

The writer wishes to acknowledge the assistance and material aid given him by the engineers at Chance Vought Aircraft. Prof. J. A. Wise, thesis adviser, has been of utmost help in his suggestions and guidance. The preliminary work on the equipment and elementary

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testing methods of C. H. Cates proved to be a great time saver and the writer is very grateful for this assistance.

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SUMMARY

This thesis presents the results of an investigation to determine the transverse shear stress within the balsa wood core of a Metalite sandwich type panel. The core strains were measured by means of SR-4 electrical resistance strain gages located within the core at 45 degrees to the neutral axis. Conversion to equivalent stress was made by the principles of the theory of elasticity.

The results are limited to a circular panel, simply supported, with a uniform normal loading.

Other limitations of the experiment were:

(1) It was impossible to ascertain whether the strain gages were orientated to the radial, tangential, or an intermediate grain axis of the balsa core. Thus average values of the elastic constants had to be used.

(2) Simply supported edge conditions were not completely realized.

INTRODUCTION

There are two problems which were considered in this thesis. The first was to determine an analytic solution for the determination of the shearing stresses within the core of a circular Metalite panel under a normal uniform load, the panel being simply supported. As far as is known, no approach to this problem has been made, however several analytic studies have been made as to the stress deformation of sandwich plates (Ref. 1, 2, 3, and 4). Some experimental work has also been done along the same line (Ref. 5, 6).

Sandwich material consists of a relatively thick core of low density material and two thin, higher density face plates. The faces are bonded to the core by an adhesive material. In the case of metalite, the core material is end grained balsa wood. The faces are aluminum alloy. The thicknesses of these for the plate tested are; .23 in. for the balsa, and .012 in. for each of the aluminum alloy faces. The core was made without attempt to differentiate between the radial or tangential direction of the grain. The properties of wood vary in each of the three directions. Fortunately the properties do not differ radically in the radial and tangential direction, so average values were taken for these two directions and they were assumed to be equivalent. The problem of the analytical solution is then complicated by non-homogeneity of the core and the faces, and the non-homogeneity within the core itself. The analytical solution will be found in Appendix A.

The second problem considered is the experimental determination of the shear stresses within the core. This problem was attacked by inserting electrical strain gages within the core and measuring resulting strains as varying normal loads were applied to the plate. The method of testing is completely discussed under the Equipment and Procedure section.

The following assumptions are made for the metalite panel used:

(1) Face parallel stresses in the core may be neglected so that all planar stresses are carried by the faces.

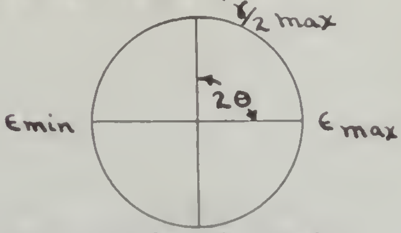
(2) The faces are very thin in comparison to the core.

(3) The neutral axis lies on the middle axis of the core.

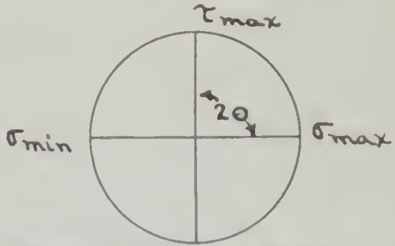
(4) The shear forces are distributed parabolically across the thickness of the core and the face plate material.

(5) The radial and tangential axes of the core display the same elastic properties.

To determine the shear distribution in the core, consider a point on the neutral axis. The Mohr circle of strain and of stress are as shown below (Ref. 8).



Mohr Circle of Strain



Mohr Circle of Stress

The values of ϵ_{max} and ϵ_{min} are determined from the experimental results. Therefore γ is known.

From the theory of elasticity, $\tau_{max} = G\gamma_{max}$

This shear stress acts at 45° to σ. As ϵ is parallel to σ and was measured on the 45° axis to the plane of the plate, the shear stress acts normal to the plate.

This investigation was carried out during the academic year of 1949-1950 at the University of Minnesota, under the supervision of Prof. J. A. Wise, thesis adviser.

EQUIPMENT AND PROCEDURE

The Metalite circular panel was a product of the Chance Vought Aircraft Company, Dallas, Texas. It had the following specifications:

Size-Diameter 30 in.
    Outside av. thickness, .26 in.
Core-End Grain Balsa. Density, 9 lb/cu. ft.
    Thickness of core, 0.23 in.
Faces-0.012 in. 75S-T6 alclad, grain of opposite faces
    parallel.
Adhesive-Redux

The testing apparatus is shown in Figure 1. A two inch thick, forty-two inch diameter circular flat steel plate was used as a base. To this base was secured a support ring made of one inch aluminum angle which had been bent on a metal shrinker to the shape of a 14-5/8 in. radius ring. The top of this angle was beaded (3/16 in dia.) allowing minimum contact area between the support and the test plate. Airtightness between the plate and the ring was made by glueing a rubber gasket to the plate along the circle of contact.

By means of a vacuum pump, air was withdrawn from the space beneath the test panel through a small hole drilled through the base plate. The amount of vacuum was regulated by a bleed valve in the air line between the panel and the pump. A second hole

drilled in the base plate allowed for an air line which led to an inclined mercury manometer. The inclination of the manometer was such that a movement of one inch of mercury corresponded to a pressure differential of 0.25 psi.

The strain gages used in the determination of the core strains were Baldwin SR-4 gages number A-8. These gages have a length of 1/8 inch (wire length) so could be contained wholly within the core. By means of a jig, slots were cut radially in the face material of the plate. Using a thin knife made from a hack saw blade, the core was pierced at 45° to the surface, joining the top and bottom slots. The strain gages were then glued to the balsa core within these piercings. The gages were mounted in pairs as shown in Figure 2. One of the gages was inclined toward the center of the plate and gave compressive readings, while the other was inclined away and gave tension readings. The adhesive used was DuPont cement #5458. When the cement had dried the strain gage lead wires were soldered to wires leading to a Baldwin SR-4 "K"- Box. The gage factor of the strain gages was 1.77 which could not be accomodated on the "K" box, so an arbitrary gage factor of 2.00 was used. Correction for gage factor was made by multiplying read values by 2.00/1.77.

Loading was made in increments of 0.25 psi. vacuum from 0 to 1.75 psi. The strain gage readings were taken from the "K" box

for each increment of loading, starting at 0 and going up to 1.75 then back down to 0 psi. A check was thus obtained for each reading. A total of five runs were made in this manner on each gage, and each of the runs checked against the others. The results were corrected for gage factor and were tabulated in Tables I, II, III, and IV and were plotted as Figures 4, 5, 6, 7, and 8.

RESULTS AND DISCUSSION

The strains of the core, as measured by the SR-4 strain gages and corrected for gage factor (Tables I, II, III, IV), were converted to average shear stress values by the relationship as explained under the Introduction section. From the Mohr circles of Stress and Strain:

$$\gamma/2 = \frac{\epsilon_{max} - \epsilon_{min}}{2}$$

$$\tau = G\gamma = 23{,}000\,\gamma$$

Values for the elastic properties of the balsa core were obtained from Ref. 7. The resulting values of τ are found in Tables V and VI.

The analytical solution, as explained in Appendix A, gave values of τ and they are found in that section. Both the experimental and the analytical values have been plotted in Figure 9 for varying normal loads. The radius used for both of these solutions was 11 inches, as the test gages were inserted at that radius.

Referring to Figure 8 and Figure 9 it is seen that the values of strain and resulting shear stress for gages #5 and #6 are much lower than the other pairs of strain gages produce. It is believed that over stressing of the plate occurred in some of the preliminary work. This resulted in an actual local splitting of the balsa wood core. If this splitting occurred in the locality

of these two strain gages, the resulting stress would be less as the split would open when the load was applied and relieve the stress in the core. This is further substantiated by the fact that when the load was applied, wrinkles appeared perpendicularly to the radius at that point. The results of gages #5 and #6 are therefore assumed to be in error and will not be discussed in this paper.

The experimental shear stress as obtained from the other sets of strain gages was found to be well within the limits of the accuracy of the experiment. The points of the curves (Figure 9) do not exhibit any noticeable irregularities. Good duplication is seen in the curves for the different sets of strain gages.

The average shear stress within the core as analyzed and experimentally determined in this paper are found to agree. No attempt to determine the exact distribution within the core or within the face plates has been made. Such an analysis would be extremely difficult and would be of questionable value.

One of the major limitations in the experimental testing of the panel was that there was no way of determining how the gages were oriented with respect to the radial or tangential grain of the balsa core. These panels are made without consideration of these grain axes. The elastic properties of balsa do vary in these two directions, however, so an average value was used. In the manu-

facture of Metalite panels, balsa boards are glued together then sliced across the longitudinal grain. Two successive slices of this core material will show similar grain patterns. It is suggested for more accurate investigation that one of the slices, mentioned above, be used in making up the test panel, and the next slice be used as a master panel to determine exactly where the strain gages are being located. If this were done, all the gages could be orientated in either the radial or tangential direction and the corresponding elastic constants could be used.

CONCLUSIONS

(1) The SR-4 strain gage method of measuring strains is satisfactory in determining the average shearing stresses within the core of a solid core sandwich type material.

(2) Both the face material and the core take shear loads.

(3) The shear stress in the face material is much higher than that in the core.

(4) The results obtained herein are satisfactory within the limits of the assumptions made and experimental accuracy.

APPENDIX A

ANALYTIC SOLUTION OF SHEAR STRESS DISTRIBUTION

A parabolic distribution of the shear stress distribution in both the face plates and the core was assumed as shown in Figure 3. It will be noted that the parabolas are symmetrical to the neutral axes of each individual material. This should be true for the core but will not necessarily be true for the face plates. If this was true, the value of the shear stress would be zero at the interface, which is hardly logical. This inaccuracy will be of small value however, and the simplification of the analysis seems to warrant it.

The general form of the equations will be:

$$\tau' = b - e\left(z - \frac{t+t'}{4}\right)^2 \qquad (1)$$

$$\tau = \tau_o - a z^2 \qquad (2)$$

At the interface we have the boundary conditions: $z = \frac{t}{2}, \tau = \tau'$

Therefore Eqs. (1) and (2) are equal:

$$b - e\left(z - \frac{t+t'}{4}\right)^2 = \tau_o - a z^2$$

$$b - e\left(\frac{t-t'}{4}\right)^2 = \tau_o - a\frac{t^2}{4} \qquad (3)$$

At the upper surface we have the boundary conditions: $z = \frac{t'}{2}, \tau' = 0$

Therefore from Eq. (1):

$$b = e\left(\frac{t'-t}{4}\right)^2 \qquad (4)$$

From the theory of elasticity, at the interface: $z = \frac{t}{2}$

$$\frac{\frac{\partial \tau'}{\partial z}}{-\frac{\partial \tau}{\partial z}} = \frac{E'}{E}$$

Substituting the differentiated form of Eqs. (1) and (2):

$$\frac{-2e(\frac{t}{2}) + 2(\frac{t+t'}{4})e}{2a(\frac{t}{2})} = \frac{E'}{E}$$

$$a = \frac{E}{E'}\left(\frac{t'-t}{2t}\right)e \qquad (5)$$

Substituting Eqs. (4) and (5) into (3):

$$\tau_0 = b - e\left(\frac{t'-t}{4}\right)^2 + a\left(\frac{t^2}{4}\right)$$

$$\tau_0 = \frac{E}{E'}\left(\frac{t'-t}{2t}\right)\frac{t^2}{4}e \qquad (6)$$

From the theory of elasticity:

$$\frac{V}{2} = \int_0^{t/2} \tau \, dz = \frac{2}{3}\tau_0 \frac{t}{2} + \frac{2}{3} b \frac{t'-t}{2}$$

$$\frac{V}{2} = \frac{E}{E'}\frac{(t'-t)}{24}t^2 e + \frac{(t'-t)^3}{48}e$$

However for a circular plate uniformly loaded:

$$V = \frac{p\pi r^2}{2\pi r} = \frac{pr}{2}$$

Substituting and solving:

$$e = \frac{3V}{t_f}\left(\frac{1}{\frac{1}{2}\frac{E}{E'}t^2 + t_f^2}\right) \qquad (7)$$

Substituting Eq. (7) in Eq. (6):

$$\tau_0 = \frac{3}{4}\frac{Vt}{(\frac{1}{2}t^2 + \frac{E'}{E}t_f^2)} \qquad (8)$$

Substituting Eq. (7) in Eq. (5):

$$a = \frac{3}{t}\frac{V}{(\frac{1}{2}t^2 + \frac{E'}{E}t_f^2)} \qquad (9)$$

Substituting Eq. (7) in Eq. (4):

$$b = \frac{3}{4}\frac{Vt_f}{(\frac{1}{2}\frac{E}{E'}t^2 + t_f^2)} \qquad (10)$$

The numerical constants for the plate tested are:

$t_f = .012$ in. $\qquad t_f^2 = .144 \times 10^{-3}$

$t = .23$ in. $\qquad t^2 = .0529$

$E/E' = 17{,}000/10.4 \times 10^6 = 1.635 \times 10^{-3}$

$E'/E = 612$

Applying these constants to Eqs. (7) thru (10):

$$e = \frac{3pr}{2 \times .012} \left(\frac{1}{.818 \times 10^{-3} \times .0529 + .144 \times 10^{-3}} \right)$$

$$= 667{,}000\ pr.$$

$$\tau_o = \frac{3/4\ pr\ .23}{2} \left(\frac{1}{.0265 + 612 \times .144 \times 10^{-3}} \right)$$

$$= .754\ pr.$$

$$a = \frac{3pr}{2 \times .23} \left(\frac{1}{.0265 + 612 \times .144 \times 10^{-3}} \right)$$

$$= 56.9\ pr.$$

$$b = \frac{3\ pr \times .012}{8} \left(\frac{1}{.818 \times 10^{-3} \times .0529 + .144 \times 10^{-3}} \right)$$

$$= 24\ pr.$$

Substituting these values into Eqs. (1) and (2):

$$\tau' = 24pr - 667{,}000(z-.121)^2 pr$$

$$\tau = .754\ pr - 56.9z^2 pr.$$

The total shear taken by the faces and the core is:

$$V_f = \frac{btf}{bt_f + \frac{1}{2} t \tau_o} \frac{1}{2} pr = .384\ pr$$

$$V_c = \frac{\frac{1}{2} t}{bt_f + \frac{1}{2} t \tau_o} \frac{1}{2} pr = .116\ pr$$

At a radius of 11 inches the core has an average shear stress:

$V_c = .116 \times 11\ p = 1.275\ p.$

$\tau_c = V_c/t_o = 1.275\ p/.23 = 5.56\ p$

For the loadings used:

P	0	0.25	0.50	0.75	1.00	1.25	1.50	1.75
τ_c	0	1.39	2.78	3.17	5.56	6.95	8.34	9.73

These values are plotted in Figure 9.

REFERENCES

1. Reissner, Eric: The Effect of Transverse Shear Deformation on the Bending of Elastic Plates. Jour. Appl. Mech., Vol. 12, No. 2, June 1945, pp A69-A77.

2. March, H. E.: Effects of Shear Deformation in the Core of a Flat Rectangular Sandwich Panel. Rpt. No. 1583, Forest Products Lab., U.S. Dept. Agriculture, May 1948.

3. Libove, Chas., and Batdorf, S. B.: A General Small-Deflection Theory for Flat Sandwich Plates. NACA TN No. 1526, 1948.

4. Reissner, Eric: Small Bending and Stretching of Sandwich Type Shells. NACA TN No. 1832, 1949.

5. Krommers, W. J., and Norris, C. B.: Effects of Shear Deformation in the Core of a Flat Rectangular Sandwich Panel Subjected to Uniformly Distributed Load Normal to its Surface-Simply Supported Edges. Rpt. No. 1583-A, Forest Products Lab., U.S. Dept. of Agriculture, October 1948.

6. Pitman, W. A., and Cleaveland, W. B.: Metalite Strength Data. Chance Vought Aircraft, Report No. 7412, July 30, 1947.

7. Doyle, D. V.: Elastic Properties of Wood. Rpt. No. 1528, Forest Products Lab., U.S. Dept. Agriculture, June 1945.

8. Wise, J. A.: Circles of Strain. Jour. Aero. Sci., Vol. 7, No. 10, August 1940.

TABLE I

SR-4 Strain Gages Located in Core

Gage Readings (micro inches)

GAGE 1 (Compression

Load psi.	1	2	3	4	5	Average	Corrected for Gage Factor
0.00	0	0	0	0	0	0	0
0.25	-41	-38	-39	-34	-43	-39.0	-44.0
0.50	-75	-74	-72	-82	-78	-76.2	-86.0
0.75	-107	-107	-102	-113	-112	-108.2	-122.4
1.00	-136	-138	-136	-142	-142	-138.8	-156.9
1.25	-163	-159	-169	-159	-168	-163.6	-184.9
1.50	-193	-190	-186	-194	-180	-188.6	-213.0
1.75	-217	-217	-216	-217	-217	-216.8	-245.0

GAGE 2 (Tension)

0.00	0	0	0	0	0	0	0
0.25	32	30	30	30	34	31.2	35.3
0.50	59	56	58	56	63	58.4	66.0
0.75	84	82	81	81	86	82.8	93.6
1.00	104	104	101	109	107	105.0	118.8
1.25	126	125	121	128	128	125.6	142.0
1.50	144	145	142	146	144	144.2	163.0
1.75	166	165	160	166	162	163.8	185.0

TABLE II

SR-4 Strain Cages Located in Core

Gage Readings (micro inches)

GAGE 3 (Compression)

Load psi.	1	2	3	4	5	Average	Corrected for Gage Factor
0.00	0	0	0	0	0	0	0
0.25	-40	-34	-38	-38	-41	-38.2	-43.2
0.50	-74	-66	-69	-70	-70	-69.8	-78.9
0.75	-102	-17	-100	-101	-108	-101.6	-114.8
1.00	-130	-128	-130	-129	-134	-130.2	-147.2
1.25	-159	-158	-160	-160	-163	-160.0	-181.0
1.50	-188	-182	-137	-186	-186	-185.8	-210.0
1.75	-208	-214	-214	-215	-217	-213.6	-241.0

GAGE 4 (Tension)

0.00	0	0	0	0	0	0	0
0.25	30	27	27	26	22	26.4	29.8
0.50	51	46	46	45	44	46.4	52.4
0.75	66	64	64	64	62	64.0	72.3
1.00	89	83	84	83	80	83.6	94.5
1.25	100	99	99	99	99	99.8	112.8
1.50	116	110	111	114	112	112.6	127.2
1.75	128	119	117	122	130	123.4	139.4

TABLE III

SR-4 Strain Gages Located in Core

Gage Readings (micro inches)

GAGE 5 (Compression)

Load psi.	1	2	3	4	5	Average	Corrected for Gage Factor
0.00	0	0	0	0	0	0	0
0.25	-18	-23	-20	-19	-20	-20.0	-23.6
0.50	-36	-40	-38	-38	-40	-38.4	-43.4
0.75	-59	-56	-55	-58	-59	-57.4	-64.8
1.00	-80	-79	-78	-78	-78	-78.6	-88.9
1.25	-102	-98	-100	-98	-98	-99.2	-112.0
1.50	-124	-119	-120	-119	-119	-120.2	-136.0
1.75	-145	-140	-139	-139	-139	-140.4	-158.8

GAGE 6 (Tension)

0.00	0	0	0	0	0	0	0
0.25	15	14	12	10	13	12.8	14.5
0.50	22	21	18	19	19	19.8	22.4
0.75	31	29	27	26	26	27.8	31.4
1.00	36	35	34	32	30	33.4	37.8
1.25	43	43	40	38	37	40.2	45.4
1.50	48	48	47	44	43	46.0	52.0
1.75	58	54	51	50	49	52.4	59.2

TABLE IV

SR-4 Strain Gages Located in Core

Gage Readings (micro inches)

GAGE 7 (Compression)

Load psi.	1	2	3	4	5	Average	Corrected for Gage Factor
0.00	0	0	0	0	0	0	0
0.25	-49	-36	-39	-45	-50	-43.8	-49.5
0.50	-80	-76	-77	-84	-80	-79.4	-89.5
0.75	-115	-112	-119	-116	-115	-115.4	-130.5
1.00	-146	-150	-149	-148	-146	-147.8	-167.0
1.25	-172	-178	-174	-174	-172	-174.0	-196.5
1.50	-197	-200	-196	-200	-197	-198.0	-224.0
1.75	-225	-227	-227	-228	-223	-226.0	-255.0

GAGE 8 (Tension)

0.00	0	0	0	0	0	0	0
0.25	20	22	20	21	22	21.0	23.7
0.50	46	49	48	50	48	48.2	54.4
0.75	69	74	72	73	73	72.2	82.4
1.00	93	95	98	99	91	95.2	107.4
1.25	113	111	110	112	108	110.8	125.0
1.50	127	127	124	128	123	125.8	142.0
1.75	140	141	138	147	136	139.2	157.5

TABLE V

EXPERIMENTAL CORE SHEAR STRESS

Gages 1 and 2

Normal load, p, psi.	ϵ max x 10^6	ϵ min x 10^6	γ = ϵ max - ϵ min	$\tau = G\gamma$
0	0	0	0	0
0.25	35.3	-44	79.3	1.82
0.50	66.0	-86	152.0	3.49
0.75	93.6	-122.4	226.0	5.20
1.00	118.8	-156.9	275.7	6.34
1.25	142.0	-184.9	326.9	7.52
1.50	163.0	-213.0	376.0	8.65
1.75	185.0	-245.0	430.0	9.90

Gages 3 and 4

0	0	0	0	0
0.25	29.8	-43.2	73.0	1.68
0.50	52.4	-78.9	131.3	3.02
0.75	72.3	-114.8	187.1	4.30
1.00	94.5	-147.2	241.7	5.55
1.25	112.8	-181.0	293.8	6.75
1.50	127.2	-210.0	337.2	7.75
1.75	139.4	-241.0	380.4	8.75

TABLE VI

EXPERIMENTAL CORE SHEAR STRESS

Gages 5 and 6

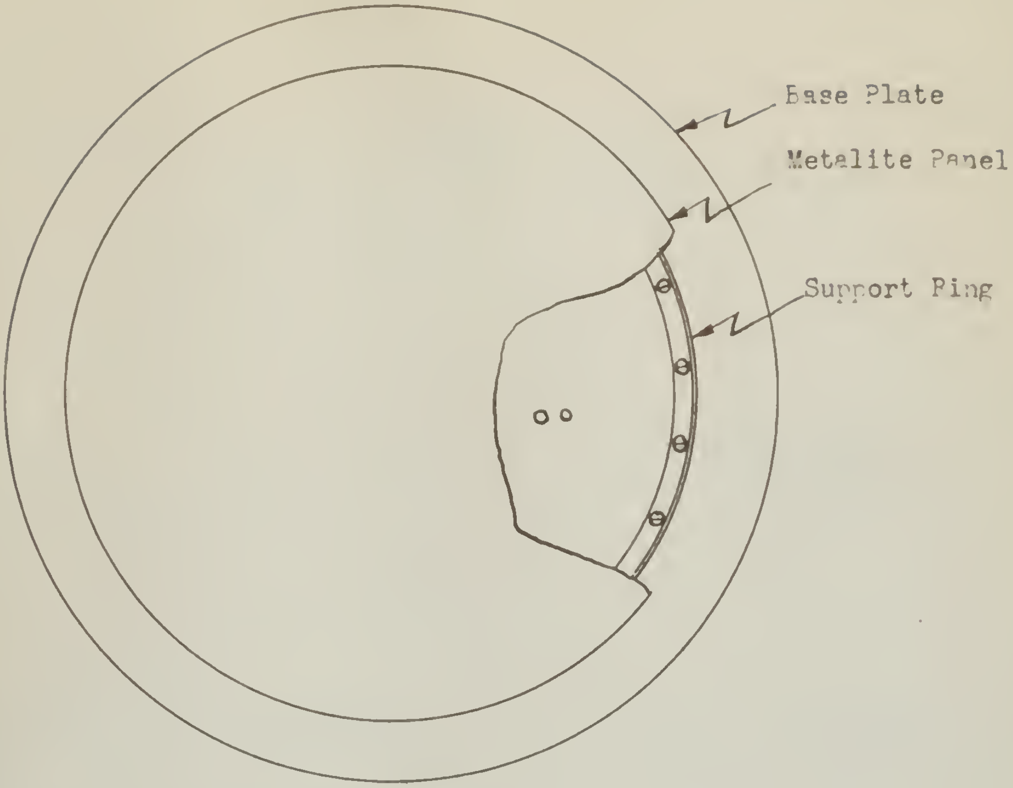
Normal load, p, psi.	ϵ max x 10^6	ϵ min x 10^6	$\gamma =$ ϵmax - ϵmin	$\tau = G\gamma$
0	0	0	0	0
0.25	14.5	-23.6	38.1	.875
0.50	22.4	-43.4	65.8	1.51
0.75	31.4	-64.8	96.2	2.21
1.00	37.8	-88.9	126.7	2.91
1.25	45.4	-112.0	157.4	3.62
1.50	52.0	-136.0	188.0	4.33
1.75	59.2	-158.8	218.0	5.01

Gages 7 and 8

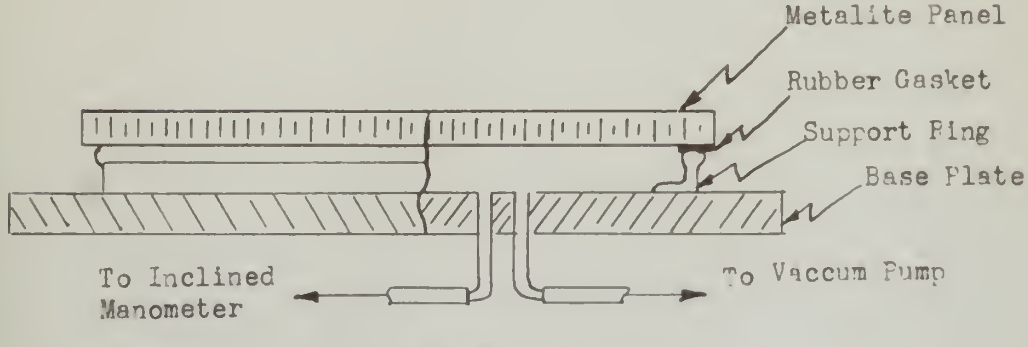
0	0	0	0	0
0.25	23.7	-49.5	73.2	1.68
0.50	54.4	-89.5	143.9	3.30
0.75	82.4	-130.5	212.9	4.90
1.00	107.4	-167.0	274.4	6.31
1.25	125.0	-196.5	321.5	7.39
1.50	142.2	-224.0	366.2	8.42
1.75	157.5	-255.0	412.5	9.49

Fig. 1.

TEST EQUIPMENT

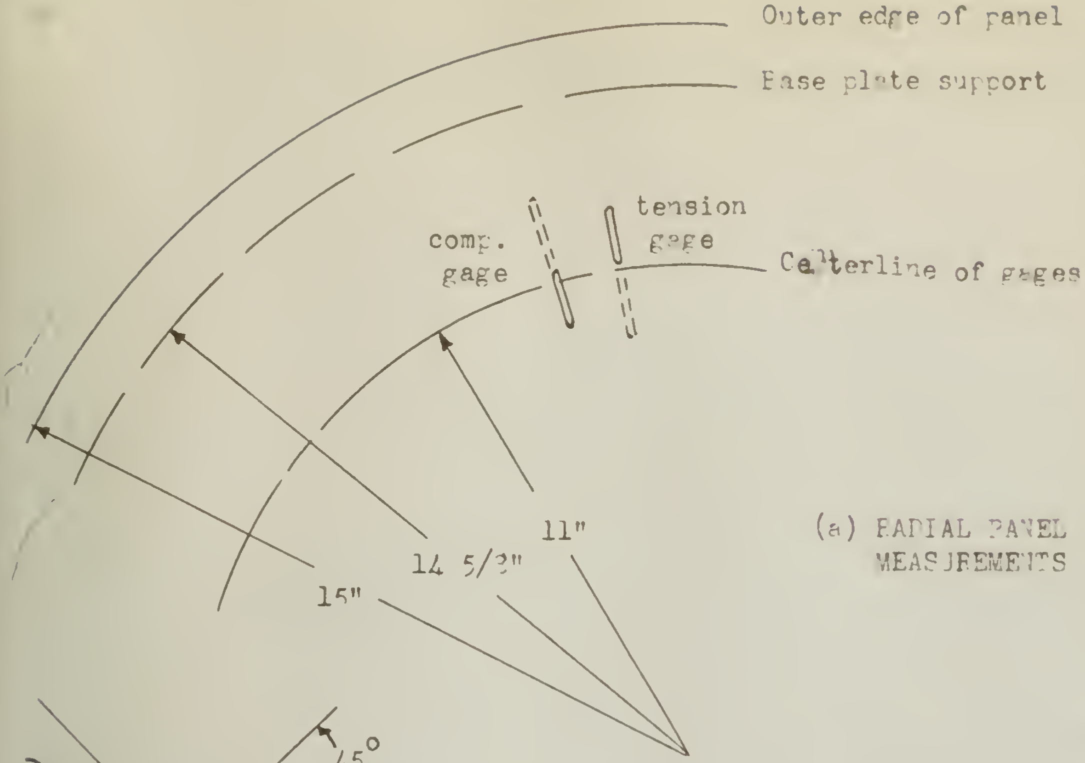

Base Plate
Metalite Panel
Support Ring

TOP VIEW

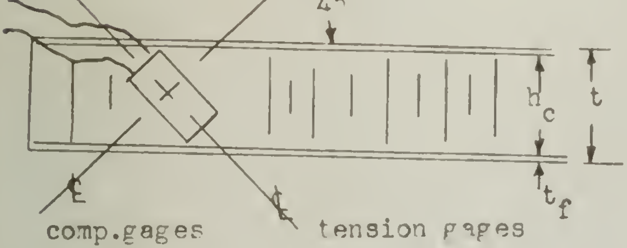

Metalite Panel
Rubber Gasket
Support Ring
Base Plate
To Inclined Manometer
To Vaccum Pump

SIDE VIEW

Fig.2.


Outer edge of panel
Base plate support
comp. gage
tension gage
Centerline of gages
11"
14 5/8"
15"

(a) RADIAL PANEL MEASUREMENTS


45°
h_c
t
t_f
℄ comp.gages
℄ tension gages

(b) GAGE INSTALLATION DETAIL (cross section)

(c) GAGE ORIENTATION

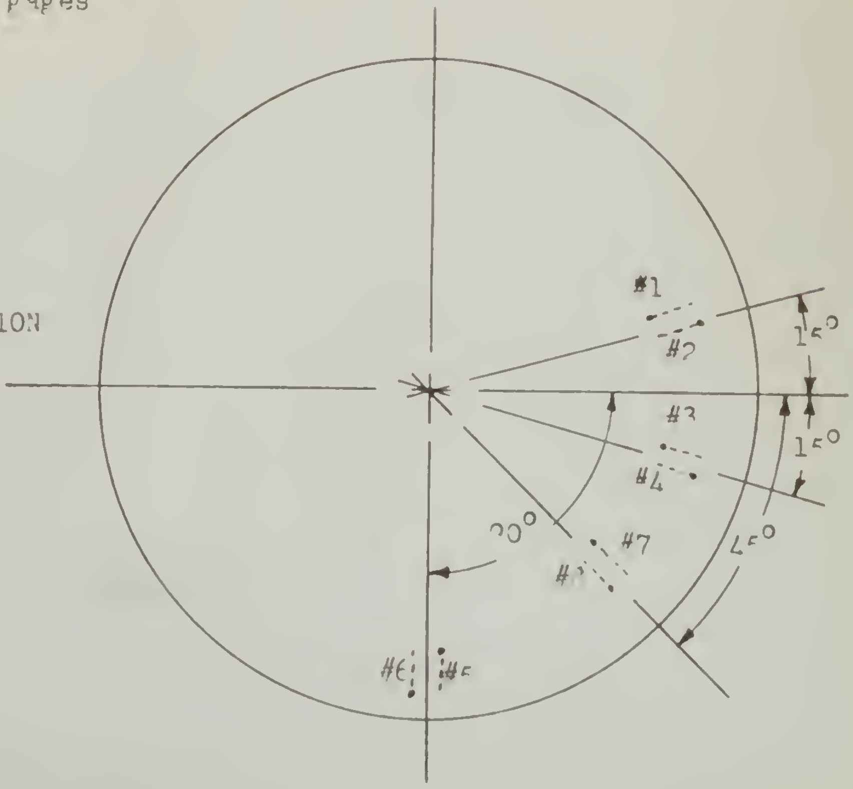

#1
#2
15°
#3
#4
15°
90°
#7
#8
45°
#6
#5

Fig. 3.

ASSUMED SHEAR STRESS DISTRIBUTION

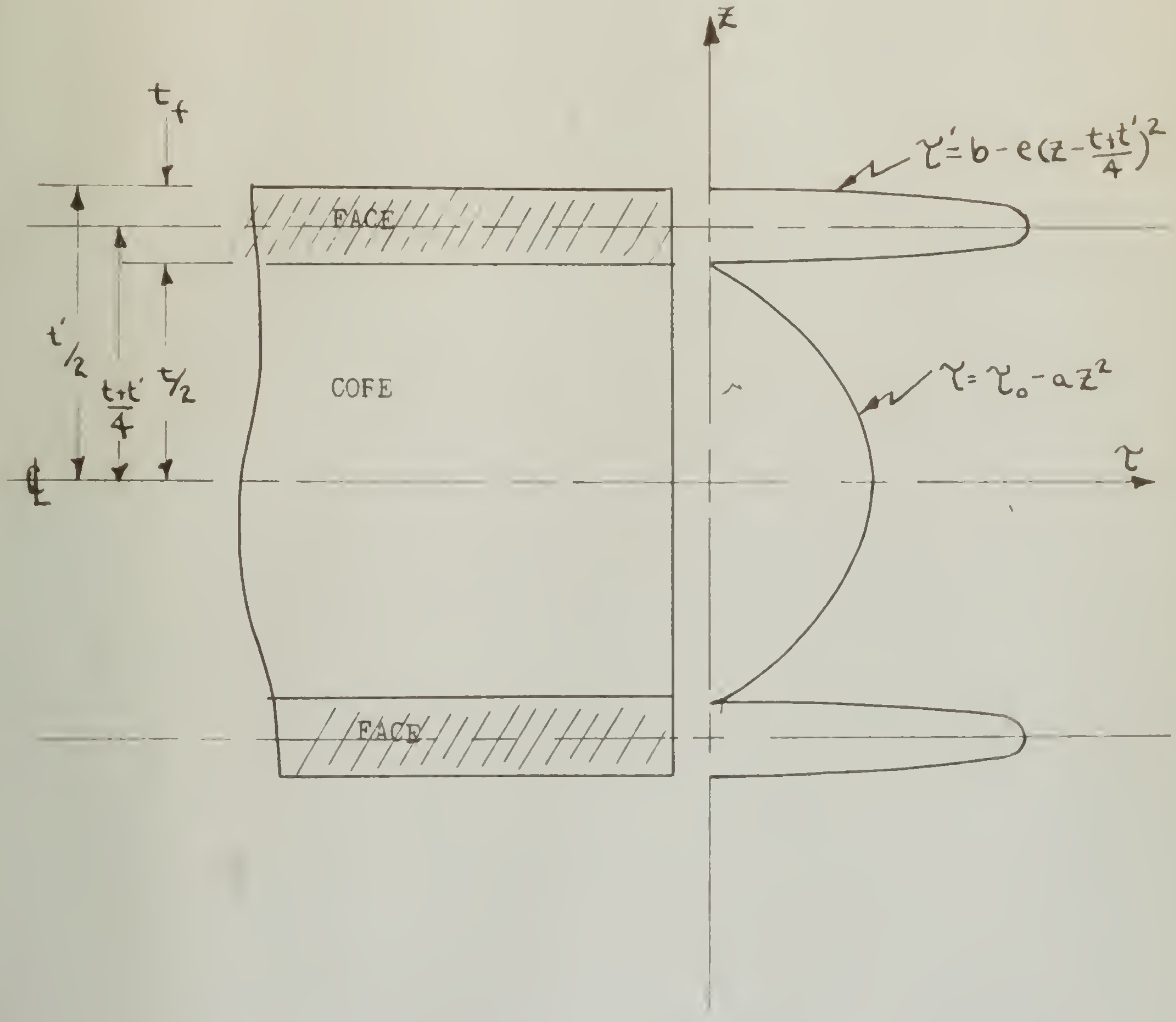
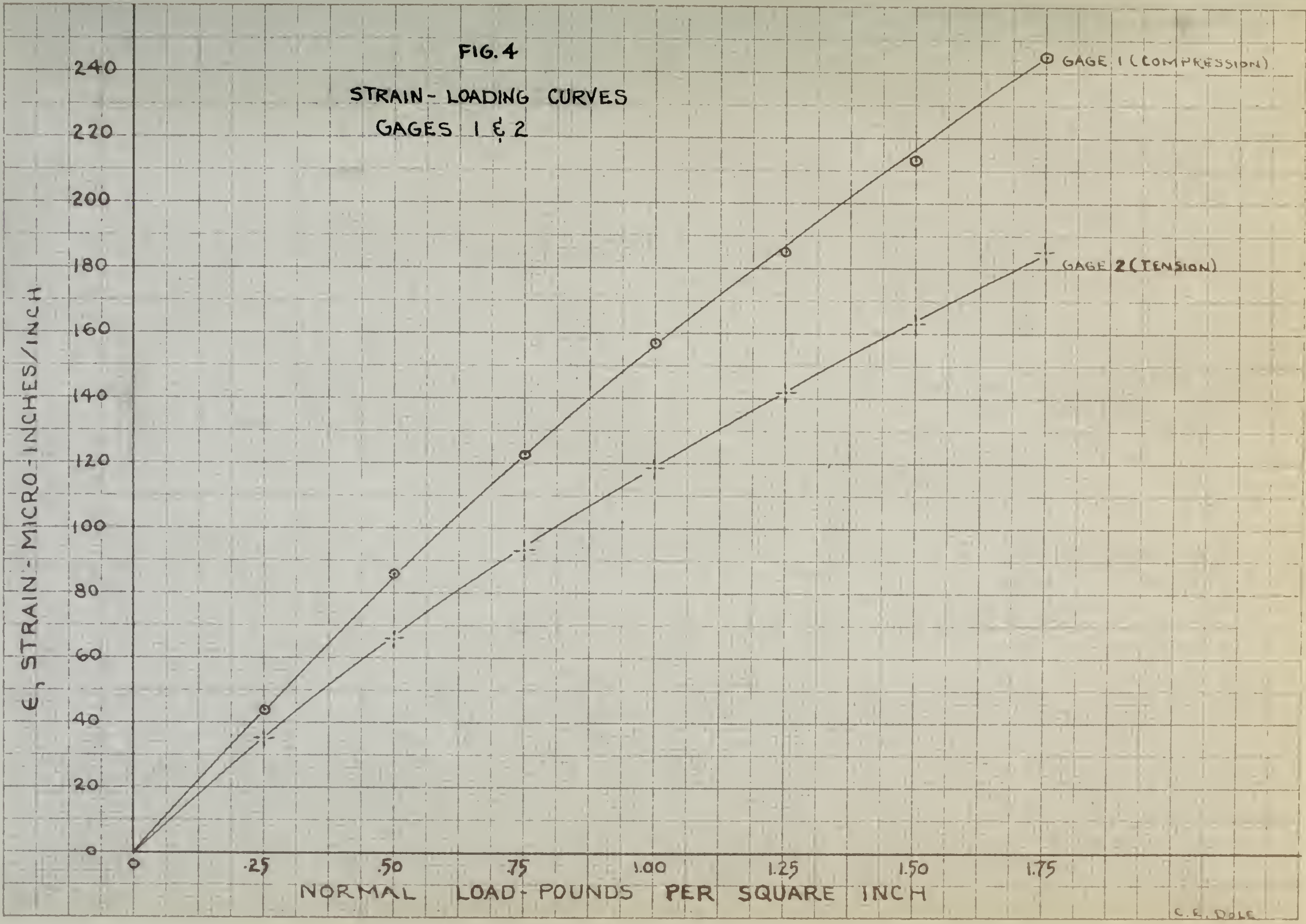

z
t_f
$\tau' = b - e(z - \frac{t+t'}{4})^2$
FACE
$t'/2$
$\frac{t+t'}{4}$
$t/2$
CORE
$\tau = \tau_0 - az^2$
τ
℄
FACE

FIG. 4

STRAIN - LOADING CURVES
GAGES 1 & 2



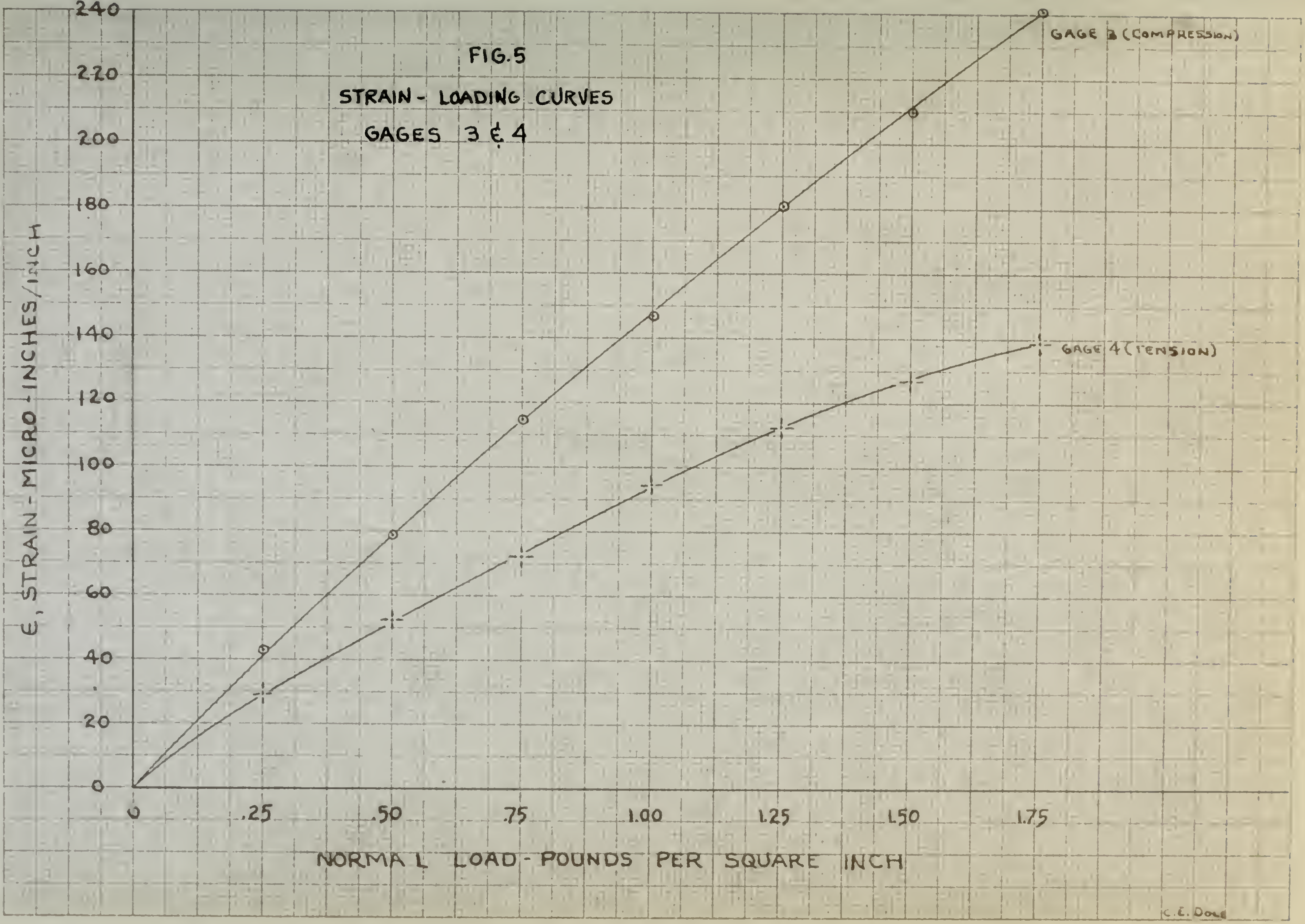


FIG.5

STRAIN - LOADING CURVES

GAGES 3 & 4

FIG. 6

STRAIN-LOADING CURVES
GAGES 5 & 6

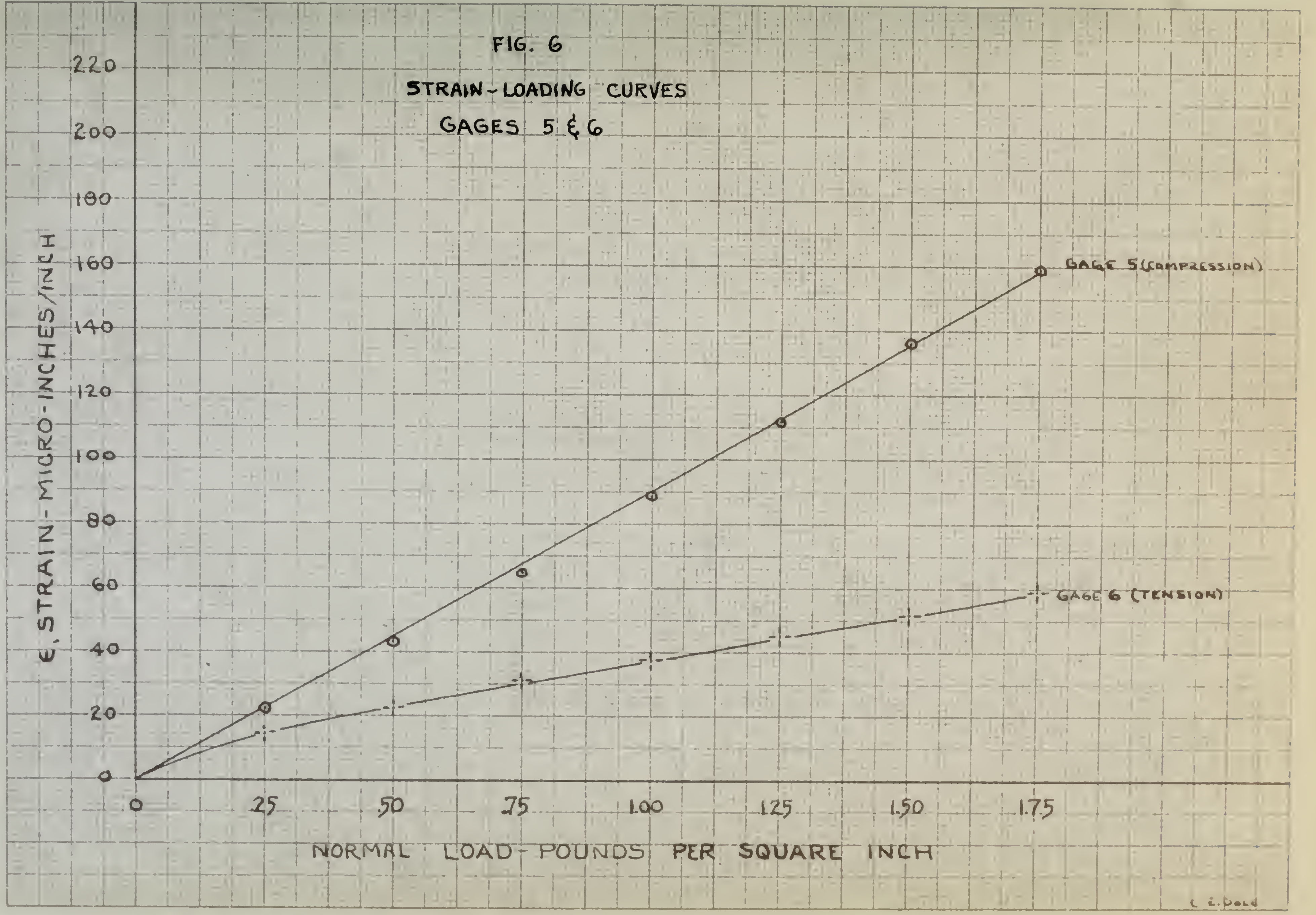


FIG. 7

STRAIN - LOADING CURVES
GAGES 7 & 8

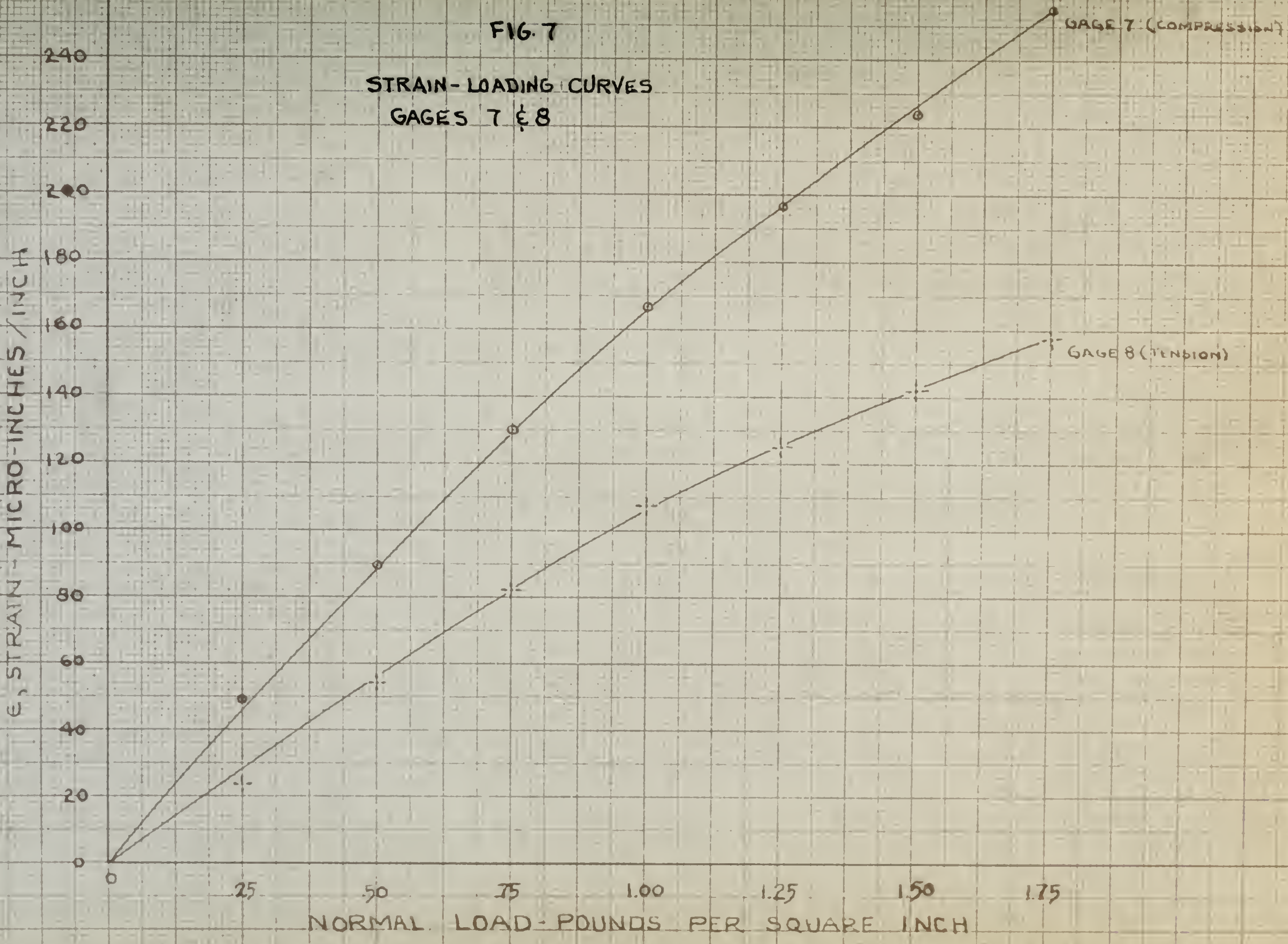
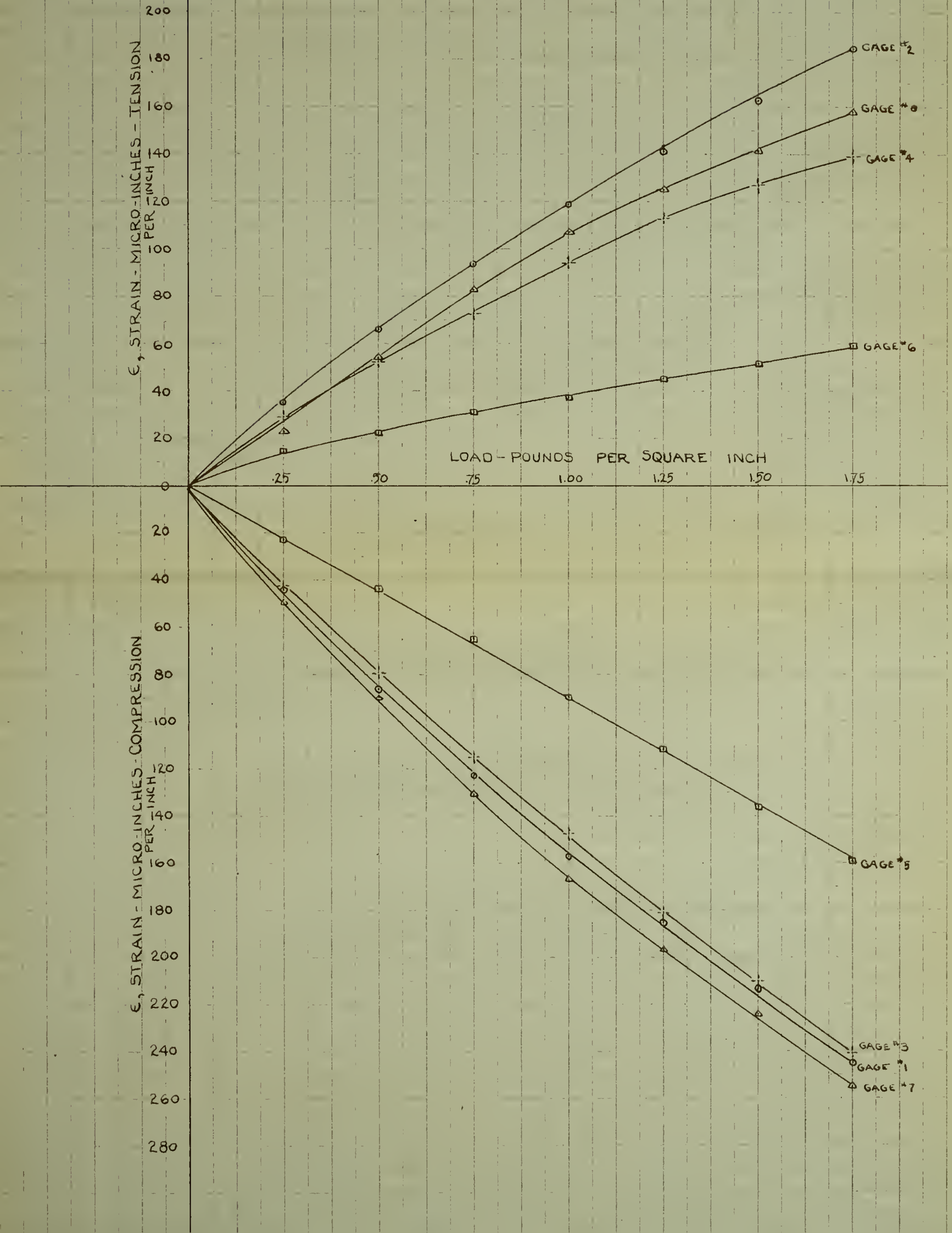


FIG. 8

STRAIN-LOADING CURVES
ALL GAGES



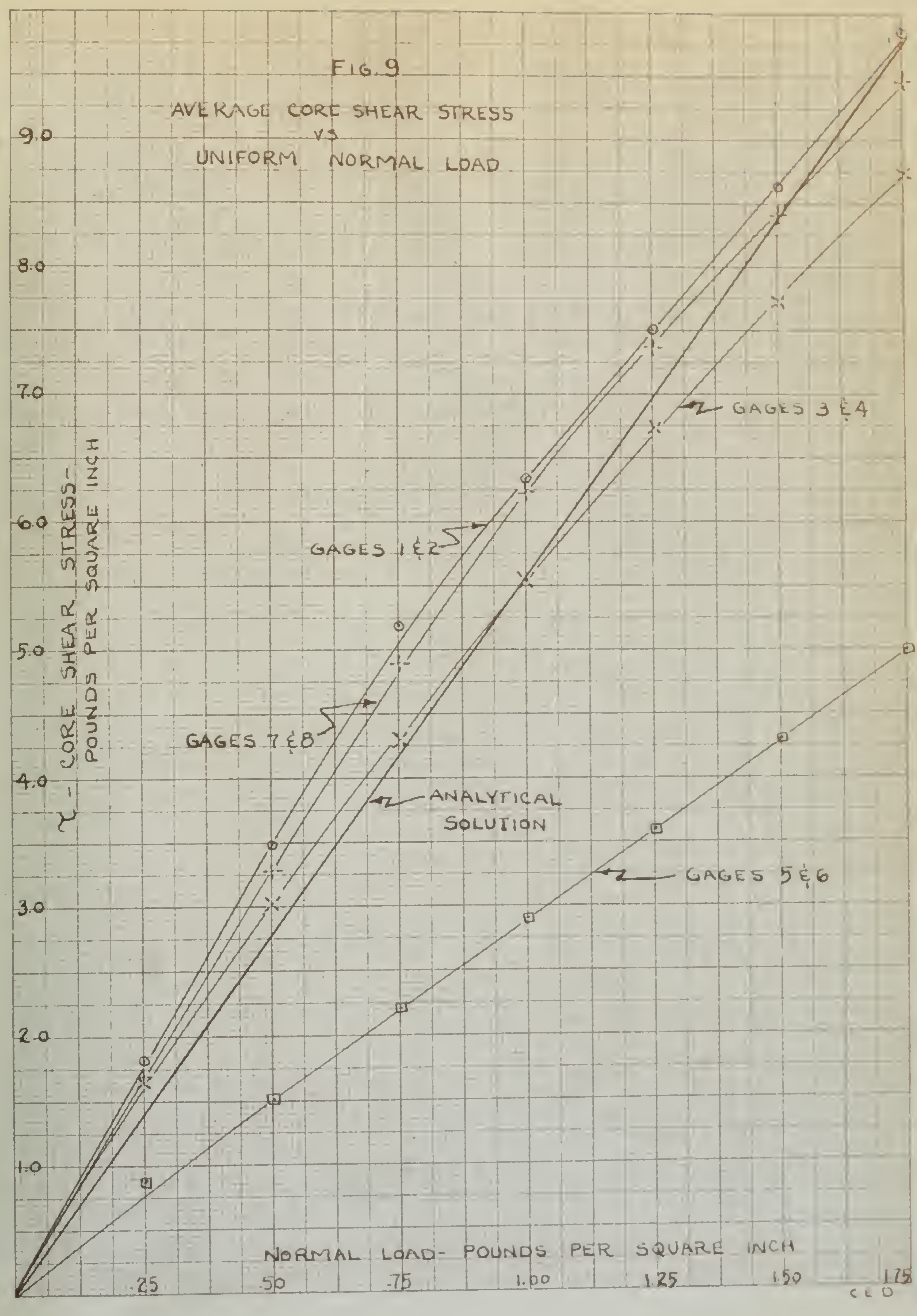


FIG. 9

AVERAGE CORE SHEAR STRESS VS UNIFORM NORMAL LOAD

DATE DUE

MY 9 64 14664

Thesis 13194
D64 Dole
Transverse shear
stress distribution in
circular metalite
plates.

Th
D6

thesD64
Transverse shear stress distribution in
3 2768 001 89460 3
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